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The Case of Transatlantic Grain Exports
in the 19th Century**

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The nature and costs of dis-equilibrium trade: The case of transatlantic grain exports in the 19th Century

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Abstract

The essential issue addressed in this paper is whether inefficient spatial arbitrage has significant welfare effects.

The paper looks at the gains from improved market efficiency in transatlantic grain trade in the period 1855-1895. It shows that there is a law of one price equilibrium but that markets display spells of demand- or supply- constrained trade. Over time adjustments back to equilibrium as measured by the half-life of a shock become faster, and adjustment parameters are much larger than routinely reported in the PPP-literature. There are also significant gains from improved market efficiency but most of that improvement takes place in one step after the information ‘regime’ shifts from pre-telegraphic communication to a regime with swift transmission of information in an era with a sophisticated commercial press and telegraphic communication. Improved market efficiency probably stimulated trade more than falling transport costs.

Keywords: market integration, error correction, law of one price.

JEL-classification: F1, C5, N7.

1. Introduction

Economic historians have neglected the study of performance of markets assuming implicitly that the existence of exchange between spatially separated markets also imply fairly well behaved, if not perfect, markets.¹ This misperception lies behind the habit of interpreting price convergence between markets as a result of transport cost reductions. In earlier work (Persson 1999) it was shown that over the last five centuries market performance improved gradually as measured by the ‘power’ of *the law of one price*. Henceforward the law of one price, LOOP, means the transport and transaction cost adjusted law of one price. In spatial arbitrage price differences persist because of transport and transaction costs between trading markets. ‘Power’ is indicated by the adjustment speed back to LOOP, provided there is such an equilibrium. However, even though long-distance market integration can be traced as far back as to the 15th century, the speed of adjustment was very low in the pre-industrial era. The process of improved market efficiency gained momentum in the 19th century with faster and more reliable means of information transmission. This came about through the emergence of a reliable postal system, the increasing sophistication of the commercial press and business news in newspapers, and the triumph of the telegraph. With the telegraph the speed at which information travelled became dramatically shorter than the speed of transporting goods. The half-life of shocks to the law of one price has declined between 1500 and 1900 from years to weeks. This conclusion might seem surprising given the evidence that aggregate price indices across nations adjust slowly and the recent authoritative conclusion that commodity market integration remains markedly imperfect and that much too little decrease in the magnitude of deviations from the law of one price has been recorded over very long stretches of time (Rogoff et al 2001). In the literature results of half-life of shocks up to a year or more are frequently reported also for fairly homogenous goods (Giovannini 1988). However, many of these studies rely on yearly or quarterly averaged price data which conceal the day to day adjustments and hence introduce a serious downward bias to the estimates (Taylor 2001).

The principal new problems addressed in this paper having first demonstrated the existence of a law of one price equilibrium is

1. to measure the costs of imperfect market integration, that is the economic costs of spatial arbitrage and trade out of LOOP, i.e. when price does not obey LOOP

¹ Many useful comments and suggestions by Cormac O Gráda and Giovanni Federico are gratefully acknowledged.

2. to document the improvements in market efficiency and to estimate the gains thereof
3. to explain the forces behind improved market efficiency.

We will develop an accounting framework for measuring the trade forgone in dis-equilibrium and, by implication, the gains from improved market efficiency. For reasons that will be explained in section 4 the word trade is used as a synonym for contract. The trade forgone is defined as the shortfall of traded (contracted) quantities when LOOP is violated from trade in the LOOP equilibrium. The intuition of the proposed framework is simple. We first determine the traded or contracted volume in the law of one price equilibrium at a particular import market, London or Liverpool, supplied by an export market, New York. If the price in London rises above the law of one price equilibrium then actual transactions, i.e. the quantities contracted, will be lower than in equilibrium since demand is smaller than in equilibrium, assuming a negatively sloped demand curve. Quantities traded are constrained by demand. If the price in London falls below the equilibrium price then transactions will be constrained by a smaller supply than in equilibrium, given an upward sloping supply curve. The costs of dis-equilibrium are the losses in terms of contracts forgone, that is the difference between the law of one price equilibrium and dis-equilibrium quantities. We do not have information on actual quantities but by specifying demand and supply elasticities we generate the slope of the demand and supply schedules which is all we need to determine an equilibrium. The forgone trade will be estimated as a proportion of the equilibrium trade.

We will examine the efficiency of spatial arbitrage by analyzing transatlantic wheat trade from the 1850's to the end of the 19th century. The periods and market pairs differ radically in that they belong to different 'information regimes'. The New York to Liverpool trade of wheat in the 1855-62 period is in the pre-telegraph era. The telegraph linking Europe and North America began to operate in 1866. However, the great shift in the transatlantic information regime did not arrive immediately after the introduction of the telegraph but in the mid 1870's. Part of the reason was that US wheat exports were quite erratic in the second half of the 1860's. Although we can imagine that big traders had private information on market conditions provided by telegraphic transmission, that information was not widely dispersed except with a considerable delay. However by the mid 1870's wheat exports were at historic peaks and the commercial press started to publish regular reports on prices on both sides of the Atlantic almost instantaneously. Market news from the New York and Chicago commodity exchanges were publicly available in Britain the next day.

We look at two pairs of markets for the period: 1878-1895 for New York to London, and 1878-1883 for New York to Liverpool.² We expect the major shift in market efficiency to be associated with the transition to an information ‘regime’ based on telegraphic transmission of information and its diffusion by a sophisticated commercial press emerging in the 1870s.

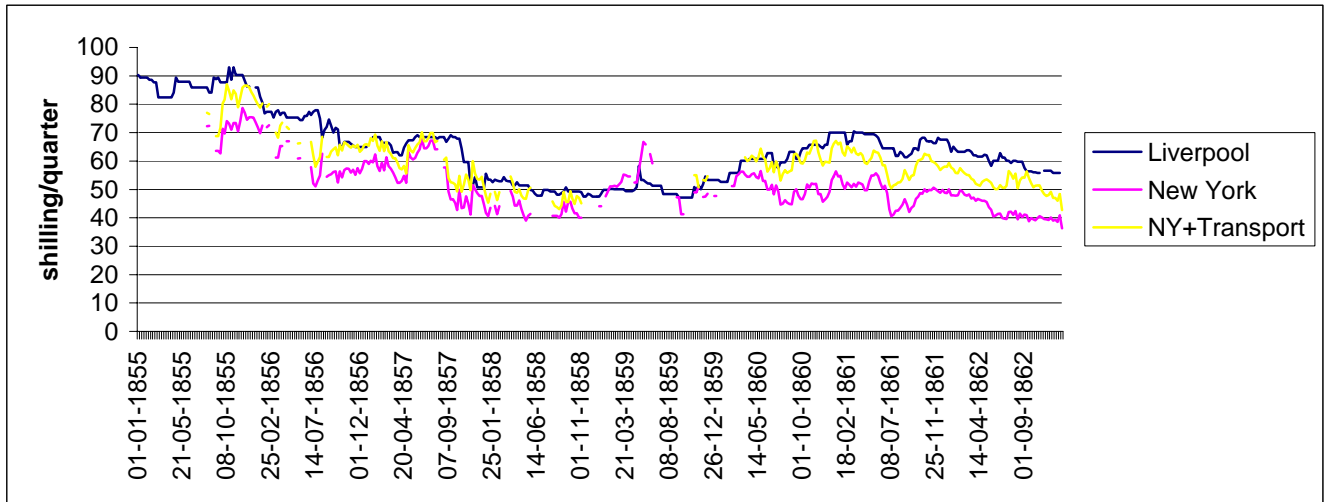
The paper is organized as follows. In section 2 the data used in the empirical analyses are described. In section 3 the nature of the law of one price equilibrium is analyzed in an error correction model. Section 4 uses a simple diagram to outline the argument of a market exhibiting demand and supply constraints of trade and the model is then formalized. In section 5 the costs of imperfect market integration are assessed. Section 6 concludes.

2. Data

The data consist of weekly observations of prices of well-defined and homogenous qualities of wheat as well as transport cost data, so-called berth rates. Our focus is on trade in one direction, from North America (New York) to UK (London and Liverpool). Other transaction costs such as insurance, port charges, commissions etc. have not been possible to register on a continuous basis in the 19th century so they are estimated as the residual between the UK price and the New York price plus transport costs. Persson (2004) provides some benchmark estimates which can serve as a standard. As a rule prices compared refer to the same weekday, usually a Monday. The sources used are described in Appendix 1. Figures 1-3 will give the reader a general view of the relationship between prices at the two locations, Liverpool or London and New York, as well as the transport costs.

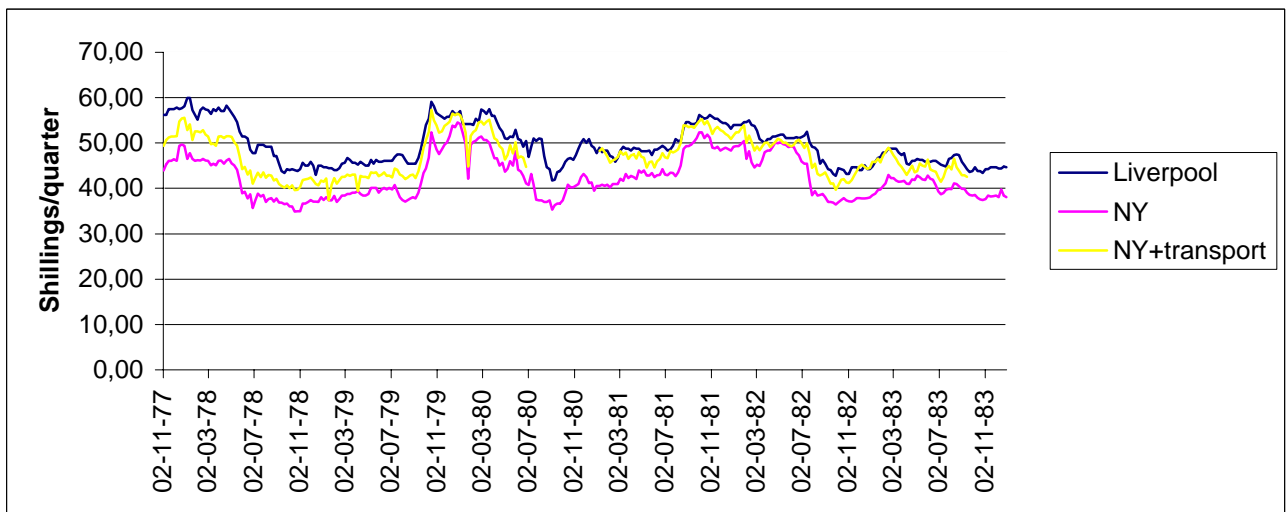
² It has not been possible to pursue an analysis on the early years of the 1870’s because the quality denominations on US wheat in New York and London and Liverpool were not identical.

Figure 1. *Prices of American white in New York and Liverpool and sail freight rates from New York to Liverpool 1855-1862. s per imperial quarter.*



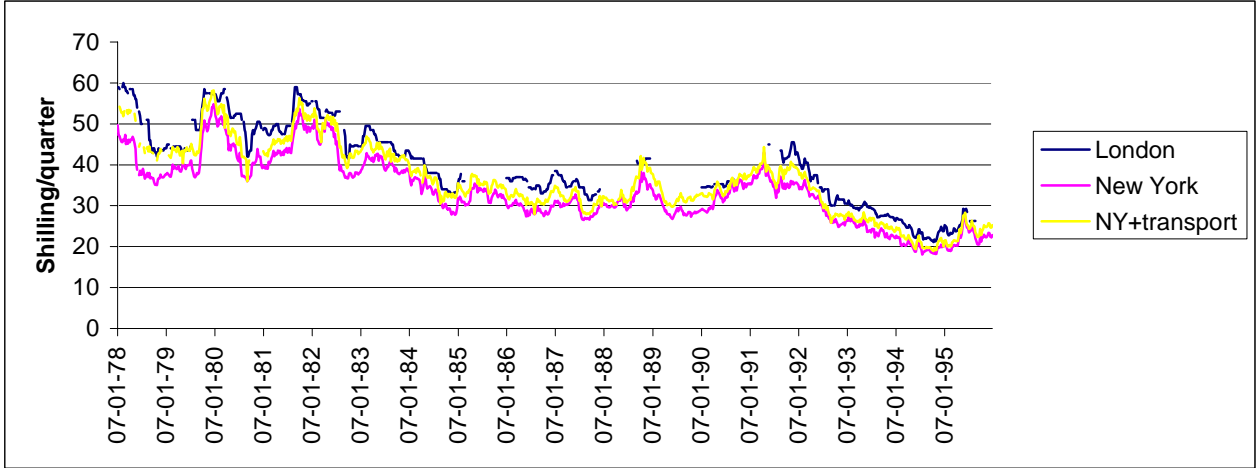
Source: *Liverpool Journal*, *Liverpool Courier*, *New York Times*. See Appendix 1 for details.

Figure 2. *Prices of Red Winter in New York and Liverpool, and steam freight rates from New York to Liverpool, 1877-1883. s per imperial quarter.*



Source: *Beerbohm's Evening Corn Trade List* (London), *The Times* (London), *Liverpool Journal*, see Appendix 1 for details.

Figure 3. *Prices of Red Winter No.2 in New York and London and steam freight rates from New York to London, 1878-1895. s per imperial quarter.*



Source: *Beerbohm's Evening Corn Trade List* (London), *The Times* (London), *Liverpool Journal*, see Appendix 1 for details.

In Figures 1-3 there is, as there should be, a positive residual between New York price plus transport costs and the UK price because of unrecorded transaction costs such as insurance and port charges.

3. The nature of the law of one price equilibrium.

In this section we derive the definition of the law of one price, where we explicitly take into account the presence of transport and transaction costs. Let P^L and P^N denote the prices in London (Liverpool) and New York. Furthermore, we also observe the transport cost, P^{Tc} . All prices are measured in the same currency and units, per imperial quarter.

The law of one price adjusted for transport and transaction costs (LOOP) implies the following equilibrium

$$P^L = (1 + \delta)(P^N + P^{Tc}) \Leftrightarrow \frac{P^L}{(1 + \delta)(P^N + P^{Tc})} = 1$$

where δ measures other transaction costs. These costs are assumed to be constant and proportional to the price in New York plus transport costs. Admittedly this is a simplification since some of the costs, for example insurance, are linked to the value of the cargo. However other costs such as

porter charges might reflect the state of the freight market, so in a sense the assumption is a compromise between conflicting concerns, which happens to simplify the analysis considerably. Deviations from the LOOP- equilibrium can be expressed in terms of differences in the logarithm of the prices:

$$\ln\left(\frac{P^L}{(1+\delta)(P^N + P^{Tc})}\right) = \ln(P^L) - \ln((P^N + P^{Tc})) - \ln(1+\delta).$$

On the basis of deviations from the equilibrium the error correction model can be derived.

Error correction modelling of spatial price adjustments is based on the insight that equilibrium is an attractor with varying degrees of power rather than a state in which economies rest. The study of actual spot markets indicates that sellers and buyers are involved in bids and counter-bids, which eventually lead them to outcomes preferable to both. Before reaching that state, time elapses and trade can be far off from equilibrium volumes. In a transport and transaction cost adjusted law of one price equilibrium the difference in price between two spatially separated markets should not exceed transport costs and other associated costs such as insurance, port charges etc. (Ejr  s and Persson 2000). If the price differential between markets exceeds what the law of one price prescribes, then profit-seeking traders would gain from arbitrage and trade and close the gap. Adjustments back to equilibrium take time and new stochastic shocks appear frequently. The fact that the adjustment after a shock is not instantaneous implies that markets are not in equilibrium during the adjustment process. That process will necessarily involve spells of negotiations, bids and counter-bids, with traded volumes lower than equilibrium trade because – as will be clarified below – trade will be constrained (relative to equilibrium levels) either by demand or supply.

The intuition behind the error correction model is that prices in London and New York will react if there is a dis-equilibrium. In this case the prices will adjust such that the deviation from equilibrium is decreasing. The error correction model is usually expressed in differences of log prices. Let $\Delta p_t^L = \ln P_t^L - \ln P_{t-1}^L$ and $\Delta p_t^N = \ln(P_t^N) - \ln(P_{t-1}^N)$. The error correction model in this version is given by:

$$\Delta p_t^L = \alpha^L \left(\ln\left(\frac{P_{t-1}^L}{(P_{t-1}^N + P_{t-1}^{Tc})}\right) - \lambda \right) + \varepsilon_t^L$$

$$\Delta p_t^N = \alpha^N \left(\ln\left(\frac{P_{t-1}^L}{(P_{t-1}^N + P_{t-1}^{Tc})}\right) - \lambda \right) + \varepsilon_t^N$$

where $\lambda = \ln(1 + \delta) \approx \delta$ and ε_t^N and ε_t^L are error terms which are assumed to be normally distributed with mean zero and constant variances:

$$\begin{pmatrix} \varepsilon_t^L \\ \varepsilon_t^N \end{pmatrix} \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_L^2 & \sigma_{LN} \\ \sigma_{LN} & \sigma_N^2 \end{pmatrix} \right).$$

The parameters of the model can be estimated using maximum likelihood techniques. This model is a special case of the general error correction model where the equilibrium relation is assumed known (for a detailed description of the error correction model see: Banerjee, Dolado, Galbraith and Hendry (1993)). The expected sign of the α^L parameter is negative and it is positive for α^N .

The estimation results

Table 1: *Estimates from the Error correction model*

US England	New York Liverpool	New York Liverpool	New York London	New York London
Period	1855-1862	1877-1883	1878-1885	1886-1895
α (US)	0.112* (0.036)	0.074 (0.044)	0.013 (0.040)	0.050 (0.040)
α (England)	-0.066* (0.019)	-0.134* (0.028)	-0.196* (0.028)	-0.187* (0.0027)
λ	0.065* (0.013)	0.052* (0.008)	0.054* (0.009)	0.092* (0.007)
Half life time of a shock (in weeks)	3.5	3.0	3.0	2.6
σ (US)*10 ⁻²	4.5	2.6	2.5	2.5
σ (England)*10 ⁻²	2.4	1.7	1.9	1.7
N	270	278	264	354

Table 1 demonstrates a number of things vital for our analysis. First, we find that λ is significant and positive, as it should be given the unobserved transaction costs which it should catch. The level of the estimated λ s is in line with the independently estimated sum of transaction costs (Persson 2004), with the possible exception of the 1885-95 period. However it is possible that the proportional weight of porter's charges and handling cost was rising, since they were labour intensive services. By 1885 the general price level had fallen and wheat prices even more and continued to do so until 1895. Wages, however, displayed some downward nominal rigidity.

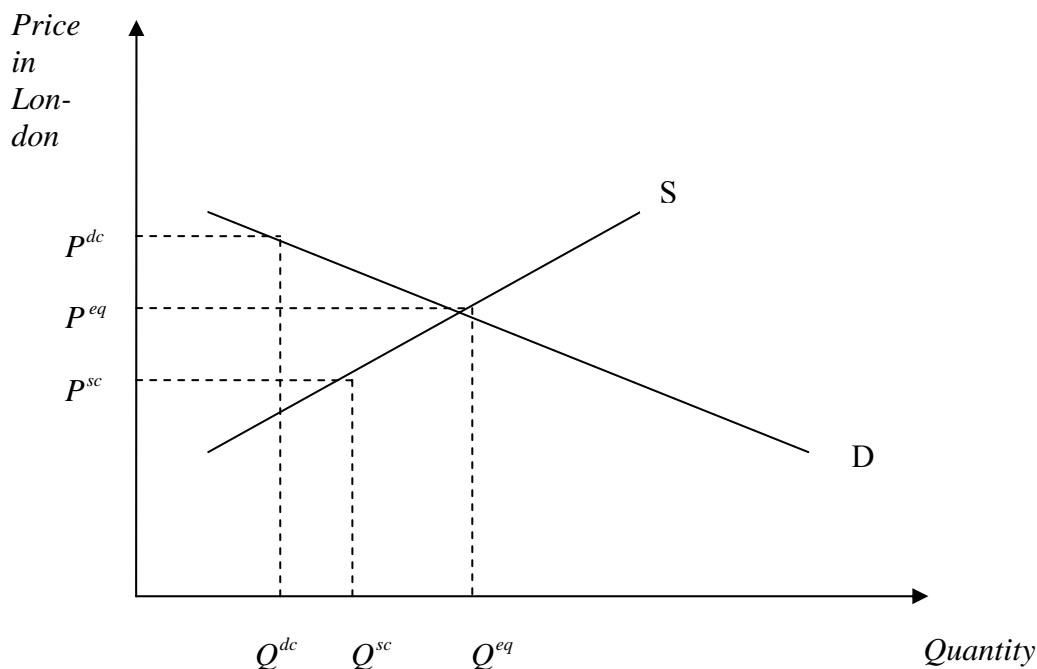
Second, there is strong adjustment to LOOP and the parameters have the right sign. A commonly used indicator of the ‘power’ of the LOOP attractor is to calculate the half life of a shock and it is falling by two weeks from 3.5 weeks to 2.6 at the end of the century.³ Third, variance in prices falls sharply. This can be interpreted as an indicator of improved market integration. Since grain is an income- and price-inelastic commodity price shocks are primarily generated by stochastic supply shocks. These shocks are, however, independent locally and tend to cancel out globally. Global supply shock variance is therefore, at least proportionally, smaller than local and integration of markets tend to reduce variance. Finally the US market tends to exhibit exogeneity in not having significant adjustment parameters except in the period 1855-1862, although the parameters have the right sign. The implication of these findings is that shocks in the US tends to dominate British prices while shocks in Britain will not affect prices in US much

4. Understanding demand and supply constraints in the trans-Atlantic wheat trade.

In the previous section we have established that prices adjust to an equilibrium determined by the transport and transaction cost corrected law of one price. In this section we analyse how demand and supply constraints can arise in the transatlantic wheat market. It is worth noting that despite the fact that the exposition of the argument relies on the notion of disturbances to a given equilibrium the analysis as such does admit for markets where you have shifts in supply and/or demand curves and by consequence the possibility of a sequence of equilibria over time. Figure 4 illustrates the general idea as stated above and applied to wheat exported from New York to London; these two local markets are assumed to represent US supply and UK demand respectively.

³ The half life of a shock is calculated as $-\ln(2) / \ln(1 - \alpha_N + \alpha_L)$.

Figure 4: *The London spot market for wheat.*



In Figure 4 the supply schedule, S , refers to the supply of US wheat in London and the demand schedule, D , to the demand for US wheat at the London spot market. The spot market deals with contracts for immediate or quasi-immediate delivery within a few days. The equilibrium price P^{eq} is the price recorded in London of US wheat which in equilibrium is equal to the price recorded in New York for the particular quality analyzed plus transport and transaction costs from New York to London. The London supply curve is simply the New York supply curve shifted upwards and the magnitude of that shift - recorded on the vertical axis - is equal to transport and transaction costs of shipping wheat from New York to London.

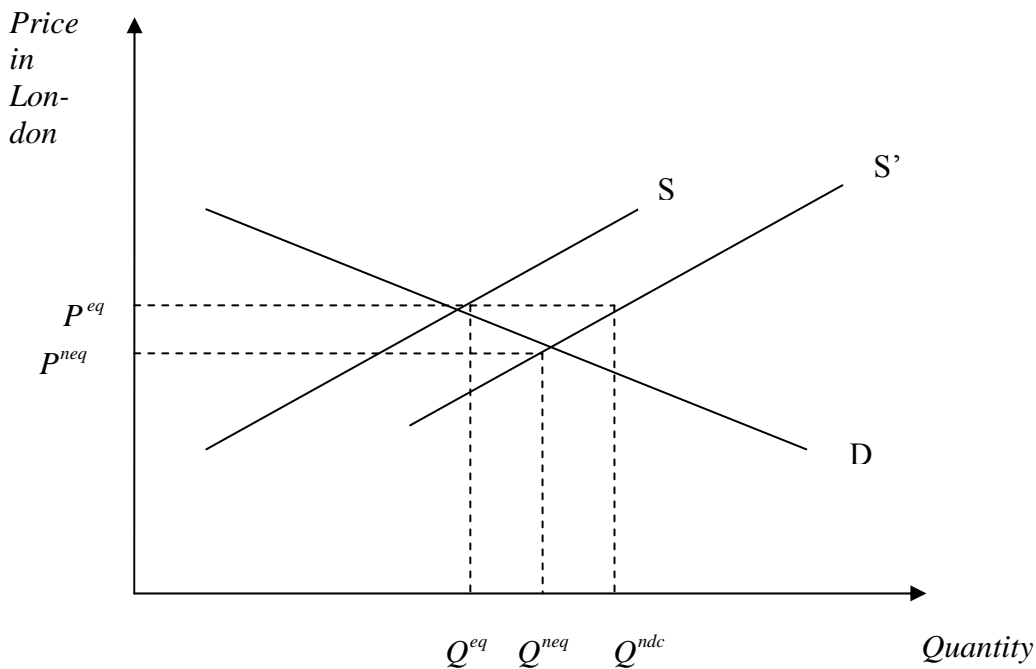
Consider now a price shock in London, from P^{eq} to P^{dc} . If so, contracted volumes decline from Q^{eq} to Q^{dc} , dc meaning demand constrained buying because the contracting will be constrained by demand relative to equilibrium demand. Traders are willing to offer more US wheat than the equilibrium quantity at that price but cannot find buyers. However the excess supply will make holders of grain to lower prices until equilibrium is reached again.

Assume instead that there is a negative price shock in London leading to a new price P^{sc} . At that price traders in London will offer Q^{sc} from their inventories, sc meaning supply constrained, the quantity equal to what can be bought and transported from New York at that price given the New York supply curve. Supply is now constrained relative to volumes offered in equilibrium. The

offered quantity, i.e. Q^{sc} , will fall short of the demand in London so we are in a situation of excess demand. When buyers chase suppliers prices will be bid up, i.e. prices will move back to equilibrium in due time.

The quantities contracted a particular market day will not necessarily equal the imports that day or the orders to New York for shipments because there are speculative inventory adjustments. For example, when prices rise above equilibrium sellers might mistake that for a permanent rise and increase their imports. However given that the actual contracts sold will be constrained by the reduced demand at above equilibrium price inventories will then build up and reduce imports at some future date when inventory levels are reduced. When price in London is below equilibrium price traders might wait until price in New York falls until they place orders and in the meantime they will reduce inventories. Over an extended period of trading sessions -- say, a couple of years -- the contracted volumes will be (approximately) equal to the actual imports in that extended period. The reason is that the difference in the volume of inventories between the initial trading session and the final market day of the trading period be very small relative to the sum of the contracted volumes during the entire period. We need not dwell on what lay behind the price shocks. We know they were frequent and the causes ranged from foreign affairs related events – wars and revolutions – the expected impact on harvest of weather conditions, monetary disturbances, disturbances in related markets, rumours etc. Buyers (sellers) get new information and on that basis the form correct and sometimes incorrect anticipations that supply (demand) schedules will shift. As noted in the introductory paragraph to section 4, the analysis pursued here does not rest on the assumption that there is one single equilibrium throughout each period or across periods. Demand and/or supply schedules can shift. It is assumed, however, that elasticities are constant, that is the slope of the supply and demand curves do not change. It is worth looking into a plausible scenario involving a downward shift in the demand schedule from the original S to S' in Figure 5. We will then have a new equilibrium quantity, Q^{neq} and a new equilibrium price P^{neq} . The estimate of contracts forgone in disequilibrium will be made relative to the new equilibrium quantity Q^{neq} . However, it is plausible that the market does not adjust to the new equilibrium price instantaneously because of price rigidities, menu costs etc, so let us assume that price remains at P^{eq} in the next trading session. At that price and given the new supply curve S' there will an excess supply since traders are willing to sell Q^{ndc} but buyers buy contracts at Q^{eq} .

Figure 5. A shift in the supply curve can generate a transitory period of excess supply and constrained demand.



This implies a situation of excess supply, which we encounter in the commercial press as reports of sellers chasing buyers, and this will put downward pressure on price so that P^{neq} is reached. In this particular case the trade forgone is the difference between Q^{neq} and Q^{eq} . It is clear from a reading of the contemporary commercial press that markets often alternated between states of excess demand or excess supply. Commercial information reported in newspapers and business journals recorded prices and the state of the market as 'quiet' or 'busy', indicating not only the volume but also the 'mood' of trade. Occasionally the recorded price was characterized as 'nominal' indicating that it was not associated with trade but just repeated from the preceding session. You find descriptions of suppliers willing to sell at a given prices with few buyers willing to negotiate a contract and the reverse situation when buyers were more than willing to buy without finding enough sellers. Following a sequence of trading sessions you can follow process in which unwilling buyers reluctantly accept the offered price or sellers willing to lower the price at which they were willing to sell. The commercial press also reports, for example, that sellers (buyers) occasionally over- shoot by refusing to sell (buy) any quantity even though price has fallen (risen) only marginally, perhaps because they expect a price fall (rise) to blow away come next trading session. If traders expect equilibrium to be restored soon it might be rational not to trade.

A formal model of demand and supply constraints

Let us now turn to a formal framework for calculating the loss to contracted volumes due to supply and demand constraints as described above.

We assume that the demand curve in London is given by

$$\ln Q_t^D = \rho_0 + \rho_1 \ln(P_t^L)$$

where Q_t^D is the demand for American wheat in London and P_t^L is the price of American wheat. ρ_1 is the price-elasticity for demand ($\rho_1 < 0$). The supply of American wheat for the English markets is determined by the following supply function:

$$\ln Q_t^S = \tau_0 + \tau_1 \ln(P_t^N)$$

where Q_t^S is the supply of American wheat for London, P_t^N is the price of American wheat in New York. τ_1 is the price elasticity of supply ($\tau_1 > 0$)

In equilibrium the price in London will be equal to the price in New York adjusted for transaction costs

$$P_t^L = (P_t^N + P_t^{Tc})(1 + \delta) = P_t^{eq}.$$

P_t^{Tc} is the transport cost from New York to London and δ measures additional transaction costs (such as port and porter charges, commissions and insurance), which are assumed to be proportional to the price in New York and transport costs. The quantity obtained at the equilibrium price is denoted $\ln Q_t^{eq}$

$$\ln Q_t^{eq} = \rho_0 + \rho_1 \ln(P_t^{eq}) = \tau_0 + \tau_1 \ln\left(\frac{P_t^{eq}}{1 + \delta} - P_t^{Tc}\right).$$

If the price in London exceeds the transaction corrected price in New York $P_t^L > (P_t^N + P_t^{Tc})(1 + \delta)$ we will observe demand constraints of wheat in London and the contracted volumes will fall. The fall

$$\begin{aligned}\ln Q_t^{eq} - \ln Q_t^D &= \rho_0 + \rho_1 \ln(P_t^{eq}) - (\rho_0 + \rho_1 \ln(P_t^L)) \\ &= \rho_1 (\ln(P_t^{eq}) - \ln(P_t^L)) = \rho_1 (\ln(P_t^N + P_t^{Tc})(1 + \delta)) - \ln(P_t^L)\end{aligned}$$

If the changes are small the left hand side of the equation above can be interpreted as the percentage fall in the contracted quantity.

On the other hand if the price in London falls below the transaction corrected price in New York $P_t^L < (P_t^N + P_t^{Tc})(1 + \delta)$ we will observe supply constraints of wheat traded in London and the actual volume of contracts will fall. That fall compared to equilibrium contracting can be expressed by

$$\begin{aligned}\ln Q_t^{eq} - \ln Q_t^S &= \tau_0 + \tau_1 \ln\left(\frac{P_t^{eq}}{1 + \delta} - P_t^{Tc}\right) - \left(\tau_0 + \tau_1 \ln\left(\frac{P_t^L}{1 + \delta} - P_t^{Tc}\right)\right) \\ &= \tau_1 \left(\ln\left(\frac{P_t^{eq}}{1 + \delta} - P_t^{Tc}\right) - \ln\left(\frac{P_t^L}{1 + \delta} - P_t^{Tc}\right) \right) = \tau_1 \left(\ln(P_t^N) - \ln\left(\frac{P_t^L}{1 + \delta} - P_t^{Tc}\right) \right)\end{aligned}$$

From the two equations for the fall in quantity, the key aspect is the deviation between the prices in London and in New York (corrected for transaction costs). In the following section we will investigate the extent of price deviations and the implied effects on trade.

5. Estimating the costs of imperfect market integration

In order to estimate the cost of imperfect market integration we will need some estimates of supply and demand elasticities. What are the likely elasticities of demand and supply? There are a number of attempts to estimate UK and US elasticities of demand and supply (Irwin 1998, Williamson 1980, 1990, Olson and Harris 1959) and on that basis demand elasticity is estimated to be in the range of 0.5 - 1 and US export supply elasticity to be between 0.5 and 1.5. While there is evidence that demand for food in general is inelastic, it could be argued that US wheat is a special case since it was a prime export quality – it sold at a premium of 5 to 10 percent relative to domestic wheat in Britain and for that reason elasticities might be higher than for food or wheat in general.

Given estimates of demand and supply elasticities we can calculate the average fall in trade compared to the equilibrium. In the short run the actual import trade of US wheat might differ from the contracts sold for immediate and quasi-immediate delivery. However, as explained in section 4 imported and contracted volumes will be approximately equal over an extended period since inventory adjustments between the initial market session and the last will be small relative to the

traded and imported volumes. For that reason we will henceforward use the word ‘trade’ as synonymous with ‘contracted volume’. The average forgone trade is calculated as:

$$\begin{aligned}\ln Q^{eq} - \ln Q^A &= \frac{n^{dc}}{N} (\ln Q^{eq} - \ln Q^D) + \frac{n^{sc}}{N} (\ln Q^{eq} - \ln Q^S) \\ &= \frac{n^{dc}}{N} \rho_1 \left(\ln((P^N + P^{Tc})(1 + \delta)) - \ln(P^L) \right) + \frac{n^{sc}}{N} \tau_1 \left(\ln(P_t^N) - \ln\left(\frac{P^L}{1 + \delta} - P^{Tc}\right) \right)\end{aligned}$$

where n^{dc} and n^{sc} are the number of periods with demand constraints and supply constraints respectively. We display the estimates of the average loss in trade in table 2 for two pairs of values of the elasticities.

Table 2: *Estimating the forgone trade due to imperfect market integration.*

US England	New York Liverpool	New York Liverpool	New York London	New York London
Period	1855-1862	1877-1883	1878-1885	1886-1895
δ	0.089 (0.078)	0.059 (0.038)	0.065 (0.043)	0.100* (0.035)
N	283	277	295	384
Demand constraint				
n^{dc}	141	123	136	211
Mean price dev.	0.060	0.035	0.038	0.025
Supply constraint				
n^{sc}	142	154	159	173
Mean price dev	-0.060	-0.031	-0.033	-0.031
Mean fall in quantity (%) ($\rho_1 = -1, \tau_1 = 1.5$)	7.5	4.1	4.4	3.5
Mean fall in quantity (%) ($\rho_1 = -0.5, \tau_1 = 0.5$)	3.0	1.6	1.8	1.4

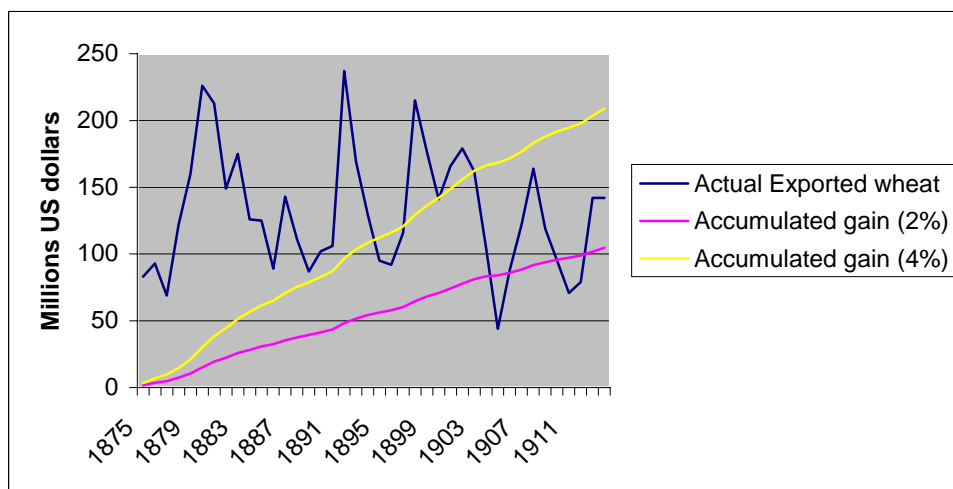
Table 2 provides an upper and lower bound estimate of the trade forgone due to deviations from LOOP trade. First conclusion is that the gains are substantial in the upper bound estimate and clearly non-trivial in the lower bound estimate. The gain from improved market efficiency is the difference in the mean fall in traded quantity between periods compared. A comparison of the 1855-62 period with the periods after 1877 reveals that the gains are at a maximum 4.5 percent and a

minimum, the lower bound estimate of the mean fall in quantity, of 1.6-1.8 percent. It means that for the latter period yearly trade was at least 1.6-1.8 per cent higher than if the market efficiency level that characterized the 1856-62 period still prevailed. Furthermore, the major improvement in market efficiency takes place, as we speculated in section 1, between the pre-telegraphic era and the first post telegraph period, that is 1877 -1883 for New York –Liverpool and 1878-1885 for New York-London.

A counterfactual

One way of assessing the importance of the gains in trade from the improved market efficiency is to design a counter-factual scenario. Imagine that no improvement in market efficiency took place after the 1856-62 period. Then trade would have been smaller than the actual trade since there was, as demonstrated in Table 2 significant improvements in market efficiency. The gain is the difference between trade in the counter-factual state (no improvement in market efficiency) and observed trade. From Table 2 we can calculate that the increase in trade in moving from the 1856-62 market characteristics to the 1876-95 market structure amounted to roughly 3.5 – 4 percent difference in traded volume each year (in the upper-bound estimate) to 1.2 to 1.6 percent in the lower-bound estimate. The counter-factual question then is: what would the accumulated gains in trade be like? The actual trade is the observed value of yearly wheat exports from USA between 1875 and 1914 measured in current US dollars and is considered to represent trade at the market efficiency characteristics reported in Table 2 for the 1876-1895 period. Had market efficiency remained at the 1856-62 level we expect, using an estimate of the gains from improved market efficiency close to the lower bound, that trade volumes had been two per cent lower each year from 1875 than observed trade. We also do the counter-factual with an upper-bound estimate with an annual effect on trade amounting to four per cent. By adding two (four) percent of actual trade each year in the 1875-1914 period you get the accumulated gains from improved market performance. The argument is made under the assumption that the nature of the New York to London and Liverpool is possible to generalise to US wheat exports in general, but given that the UK was the major market and London and Liverpool the dominating markets in Britain, that assumption is not unreasonable.

Figure 6. *Actual US wheat exports and accumulated gains from improved market efficiency, 1875-1914 in a lower-bound and upper-bound estimate of market efficiency gains.*



Source: Mitchell, B.R., *International Historical Statistics, The Americas 1750-1988*, New York: Stockton Press, 1993, Table E 3.

Figure 6 indicates that the accumulated gains from improved market efficiency using the average of the upper and lower bound estimates were a little larger than one year's average trade in a 40 years period. Is that gain big or small?

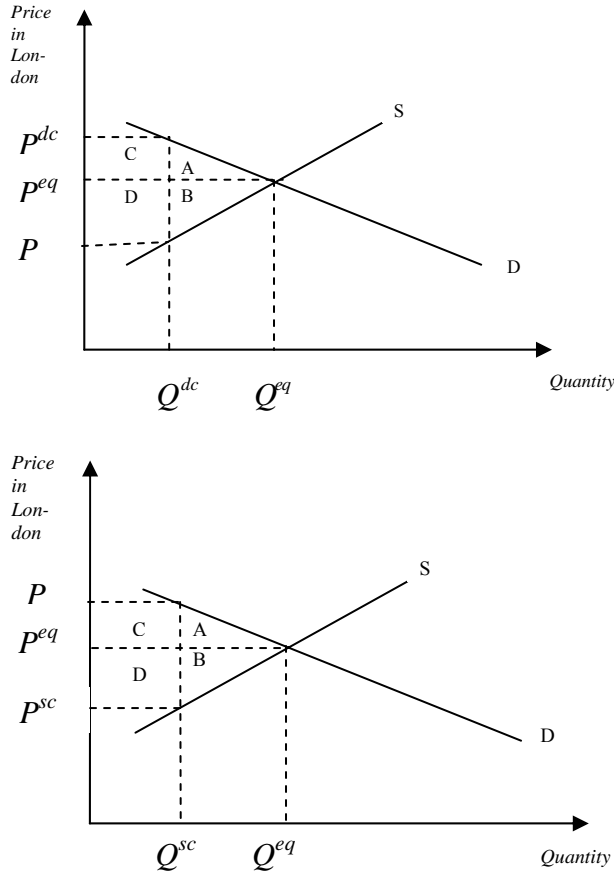
One way of addressing that question is to look for a standard. In the conventional view transatlantic trade flourished in the second half of the 19th century mainly because of falling international freight rates (O'Rourke and Williamson 1999). It makes sense therefore to assess the impact of market efficiency gains compared to the gains in trade attributed to falling transport costs. In this context the relevant way to approach transport costs is to calculate so-called freight factors, i.e. freight rates as a proportion of commodity prices, e.g. the cost of shipping a bushel of wheat as proportion of the wheat price. Calculating freight factors is appropriate when the focus is on the trade-inhibiting bias of transport costs. If freight charges fall these gains will be distributed between consumers and producers. Producers might catch part of the gains by increasing commodity prices and consumers might enjoy falling prices. If prices increase in the producing areas – relative to what prices would be like in the absence of falling transport costs – export supply will be stimulated meeting the increased import demand due to falling prices in Europe. We want to know by how much. Recent estimates of the fall in the transatlantic freight factor for wheat shows that it fell by approximately 3.5 percentage points between 1850 and 1900, from c.10.5 to 7 percent. (Persson 2004) Almost all of that decline took place between 1875-1895. Imagine a case in which the falling transport costs

were equally divided between producers and consumers. Producers would then enjoy prices about 1.75 percent higher by the end of the 19th century because of falling transport costs relative to a situation without transport costs reductions. But since the transport costs fell over a period of 20 to 25 years the average contribution to producers for the 1875-1900 period was closer to 1 percent. This is considerably less than the decrease in the mean deviation of price from equilibrium price between the first period (1856 – 1862) and the following periods in the lower bound estimate. Assuming the same supply response from a one per cent price increase and a one percent decrease in the mean deviation from equilibrium price it is clear that market efficiency gains matter.

The deadweight loss

Another way of addressing the magnitude of market imperfections is to calculate the dead weight loss involved. In the case where market imperfections lead to an increase in the price of the imported good above the equilibrium price the analogy to the dead weight loss of a tax is straightforward. The increase in the price above equilibrium price can be seen as a tax accruing to traders. Assume that the prices increase from the equilibrium price P^{eq} to P^{dc} . Consumer's surplus is the sum of the areas C and A and producer's surplus the sum of D and B. However, the sum of C and D is a gain for traders. As a consequence the dead weight loss is in this case equal to the area of two triangles A and B (see figure 7a). When market imperfections actually cause the price of the imported good to fall below the equilibrium price the analogy with the dead weight loss is less obvious, i.e. in case of supply constraints. As in the previous case the producer's and consumer's surplus is the areas A+B+C+D. C plus D can be interpreted as a 'gain' for consumers in that they are willing to pay the price P for the quantity Q^{sc} . Thus in this case too, the price distortions will cause a dead-weight loss equal to the area of A and B (see figure 7b).

Figure 7: The dead weight loss in the case of demand constraints (upper figure) and supply constraint (lower figure)



In our framework we cannot directly calculate the actual dead weight loss, however, we can calculate the dead weight loss as a fraction of the value of the traded quantity in equilibrium. In the case of demand constraints the dead weight loss is given by

$$DWL = \text{area A} + \text{area B} = 1/2(P^{dc} - P^{eq})(Q^{eq} - Q^{dc}) + 1/2(P^{eq} - P)(Q^{eq} - Q^{dc})$$

The dead weight loss relative to the value of the traded quantity is given by (for further details see appendix 3)

$$\frac{DWL}{P^{eq}Q^{eq}} \approx \frac{1}{2}(\ln(P^{dc}) - \ln(P^{eq}))^2(-\rho_1 + \frac{1}{\tau_1})$$

In the case of supply constraints the relative dead weight loss can be calculated as

$$\frac{DWL}{P^{eq}Q^{eq}} \approx \frac{1}{2}(\ln(P^{sc}) - \ln(P^{eq}))^2(\tau_1 - \frac{1}{\rho_1}).$$

From the expression of the dead weight loss it is seen that dead weight loss depends on the squared deviations from the equilibrium price. On the basis of the representation, we can calculate the dead weight loss from the data.

Table 3: *Estimating the Dead weight loss due to imperfect market integration.*

North America England	New York Liverpool	New York Liverpool	New York London	New York London
Period	1855-1862	1877-1883	1878-1885	1886-1895
Demand constraint				
n^{dc}	141	123	136	211
Mean sq price dev. 10^{-3}	6.18	1.94	2.51	1.03
Supply constraint				
n^{sc}	142	154	159	173
Mean sq price dev 10^{-3}	7.10	1.47	1.77	1.95
Dead weight loss (%) ($\rho_1 = -1, \tau_1 = 1.5$)	0.70	0.17	0.22	0.15
Dead weight loss (%) ($\rho_1 = -0.5, \tau_1 = 0.5$)	0.83	0.21	0.26	0.18

Estimates of deadweight loss from price distortions caused by monopolies usually come down to small numbers and our results are no different. However, what matters more is the marked decline in the deadweight loss from the first period to the last three periods. The deadweight loss is reduced to about one-fourth of its initial level and that result reinforces the conclusion that big difference in market efficiency is associated with two different information ‘regimes’, the pre- versus the post-telegraphic age.

6. Conclusion.

This paper brings a number of novel insights.

The LOOP is alive and kicking in the nineteenth-century international economy. Adjustment speed as measured by half life of shocks to LOOP was not a matter of years or months but weeks, and it fell over time. That result underlines the need for high frequency data in historical PPP-studies.

A method by which the costs of dis-equilibrium and, by implication, the gains from improved market efficiency can be measured has been developed. Gains are substantial in an upper bound estimate and non-trivial in a lower bound estimate.

Market efficiency increases over time but there seems to be a regime shift caused by changes in the information technology associated with the telegraph and the development of the business press.

But are these gains measured as ?trade growth in trade? big or small? It depends on the standard used. The impact of improvements in market efficiency compares well with the impact of the force normally ascribed a leading role, i.e. falling transport costs.

In sum, the distortions to trade generated by market imperfections did not cause intolerable damage to trade but were big enough to merit attention.

Appendix 1: Description of the data.

Prices refer to spot transactions first market day every week, usually Monday, (Tuesdays in Liverpool) and have been converted to shillings per imperial quarter. New York prices and transport costs to London and Liverpool from *New York Times*. London prices from *The Times*. Liverpool prices from *Liverpool Journal* and *Liverpool Courier*. From 1876 wheat refers to Red Winter (No.2). For the period 1856-62 New York prices are an average of white qualities and while Liverpool prices refer to American White. Exchange rates from J.Schneider et al (eds) *Währungen der Welt I, Europäische und Nordamerikanische Devisenkurse, 1777-1914*, Vol 1, Stuttgart: Franz Steiner Verlag, 1991.

Appendix 2: Test for unit root

Estimation of the error correction model relies on the assumption that the time series

$\Delta \ln P_t^L$, $\Delta \ln P_t^N$ and $\ln(P_t^L) - \ln(P_t^N + P_t^{Tc})$ are stationary processes. To examine if this is the case the Dickey-Fuller test for a unit root (non-stationarity) is performed. In the Table below the results of the test are reported.

Table A2: Dickey-Fuller test for unit root

Period	Time Series	test-statistic	Critical value (5% level)	N	Stationary/ Non-stationary
1855-1862	Liverpool	-21.93	-1.95	404	Stationary
	New York	-18.76	-1.95	282	Stationary
	Equilibrium	-5.618	-2.87	263	Stationary
1877-1883	Liverpool	-15.90	-1.95	320	Stationary
	New York	-18.74	-1.95	320	Stationary
	Equilibrium	-6.02	-2.88	272	Stationary
1878-1885	London	-12.75	-1.95	263	Stationary
	New York	-19.02	-1.95	412	Stationary
	Equilibrium	-5.95	-2.88	247	Stationary
1886-1895	London	-14.88	-1.95	329	Stationary
	New York	-24.46	-1.95	572	Stationary
	Equilibrium	-7.11	-2.88	351	Stationary

Appendix 3: dead weight loss

We derive how the relative dead weight loss can be calculated. The dead weight loss relative to the value of the traded quantity is given by

$$\begin{aligned}
\frac{DWL}{P^{eq}Q^{eq}} &= \frac{(P^{dc} - P^{eq})(Q^{eq} - Q^{dc}) + (P^{eq} - P)(Q^{eq} - Q^{dc})}{2P^{eq}Q^{eq}} \\
&= \frac{1}{2} \left(\frac{(P^{dc} - P^{eq})}{P^{eq}} + \frac{(P^{eq} - P)}{P^{eq}} \right) \frac{(Q^{eq} - Q^{dc})}{Q^{eq}} \\
&= \frac{1}{2} \left(-\frac{(P^{dc} - P^{eq})}{P^{eq}} + \frac{(P - P^{eq})}{P^{eq}} \right) \frac{(Q^{dc} - Q^{eq})}{Q^{eq}}
\end{aligned}$$

If we then use the approximation that $\ln(1+x) \approx x$ when x is small we get

$$\frac{DWL}{P^{eq}Q^{eq}} \approx \frac{1}{2} \left(-(\ln(P^{dc}) - \ln(P^{eq})) + (\ln(P) - \ln(P^{eq})) \right) (\ln(Q^{dc}) - \ln(Q^{eq}))$$

To derive the final expression where the dead weight loss is expressed in terms of the price deviations from equilibrium we use the expression of the demand curve to get

$\ln(Q^{dc}) - \ln(Q^{eq}) = \rho_1 (\ln(P^{dc}) - \ln(P^{eq}))$ and the expression of the supply curve to get

$\ln(P) - \ln(P^{eq}) = \frac{1}{\tau_1} (\ln(Q^{dc}) - \ln(Q^{eq})) = \frac{1}{\tau_1 \rho_1} (\ln(P^{dc}) - \ln(P^{eq}))$. The dead weight loss can be

written as

$$\begin{aligned}
\frac{DWL}{P^{eq}Q^{eq}} &\approx \frac{1}{2} \left(-(\ln(P^{dc}) - \ln(P^{eq})) + \frac{1}{\rho_1 \tau_1} (\ln(P^{dc}) - \ln(P^{eq})) \right) \rho_1 (\ln(P^{dc}) - \ln(P^{eq})) \\
&= \frac{1}{2} (\ln(P^{dc}) - \ln(P^{eq}))^2 \left(-\rho_1 + \frac{1}{\tau_1} \right)
\end{aligned}$$

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